6.3 ARCHITECTURAL COMPONENTS

6.3.4 CEILINGS

6.3.4.1 SUSPENDED ACOUSTIC LAY-IN TILE CEILING SYSTEMS

Suspended acoustic ceiling systems are used widely in many types of buildings. These ceiling systems often include lay-in lighting and openings for air diffusers and sprinklers heads.

TYPICAL CAUSES OF DAMAGE

- Differential movement of the ceiling relative to structural elements such as columns or walls or nonstructural elements such as partitions, sprinklers heads, or fixed lighting may damage the ceiling.
- Acoustical tiles may be dislodged and fall out of the ceiling grid; lights, diffusers, and sprinkler heads may swing and damage the ceiling; runners and cross runners in the grid may separate and fall. Ceiling systems are especially vulnerable at the perimeter or at penetrations, such as a column, pipe chase, or fixed lighting.
- Where lights, diffusers and other services within the ceiling do not have independent safety wires, these items can fall and create a hazard for occupants.
- Conflicts between ceilings and sprinkler heads are a common occurrence causing damage to both the ceiling and sprinkler heads as well as water damage due to sprinkler leaks.
- Ceiling failures may result in building evacuations and loss of functionality until the ceiling and utilities are repaired. In a hospital setting or clean lab, the failure of the ceiling system may introduce dust and debris, including asbestos, into the room below compromising its functionality. In the case of asbestos contamination, this may involve costly removal before functionality can be restored.

Damage Examples

Figure 6.3.4.1-1 Failure of suspended ceiling system including lights, air diffusers, and insulation in control room of an industrial plant in the 2001 magnitude-8.4 Peru Earthquake (Photo courtesy of BFP Engineers).

Figure 6.3.4.1-2 Failure of suspended ceiling system including lights and air diffusers in the 1994 Northridge Earthquake (Photo courtesy of Wiss, Janney, Elstner Associates).

Figure 6.3.4.1-3 Generalized failure of ceiling grid, tiles, lights, and diffusers at the Los Angeles Hospital in the 2010 magnitude-8.8 Chile Earthquake (Photo courtesy of Bill Holmes, Rutherford & Chekene).

Figure 6.3.4.1-4 Fallen ceiling tiles at Talca Hospital in the 2010 Chile Earthquake, in spite of the use of clips as shown in detail at right. Most ceilings observed in Chile did not have seismic detailing (Photos courtesy of Bill Holmes, Rutherford & Chekene).

SEISMIC MITIGATION CONSIDERATIONS

- Standard practice for the seismic design of suspended acoustic lay-in tile ceilings is described in ASTM E580, *Standard Practice for Installation of Ceiling Suspension Systems for Acoustical Tile and Lay-in Panels in Areas Subject to Earthquake Ground Motions* (ASCE, 2010), which is referenced in ASCE 7-10 Section 13.5.6. This standard supersedes several previous CISCA standards.

- For ceilings in Seismic Design Category C, the objective of these standards is to provide an unrestrained ceiling that will accommodate the movement of the structure during a seismic event. This is achieved by specifying the strength of grid connectors, frequency of hangers, perimeter closure angles, edge clearances, etc. For ceilings in Seismic Design Category D, E & F, the objective of these standards is to provide a restrained ceiling with connection to the perimeter wall and with rigid or non-rigid bracing assemblies. This is achieved by specifying the strength of grid elements, grid connections, frequency of hangers and lateral bracing assemblies, 2" minimum perimeter closure angles, minimum edge clearances, etc. For Seismic Design Category D, E & F, lateral bracing assemblies are required for all ceiling areas greater than 1000 sq. ft. There are several exemptions as follows:
    - Seismic detailing is not required for suspended ceilings less than or equal to 144 sq. feet that are surrounded by walls or soffits that are laterally braced to the structure (this exemption applies to heavy or light suspended ceiling systems).
    - For ceilings in Seismic Design Category C weighing less than 2.5 psf, special seismic perimeter closure details are required to provide an unrestrained ceiling; bracing assemblies are not required.
    - Ceilings weighing above 2.5 psf in Seismic Design Category C and ceilings in Seismic Design Categories D, E & F are detailed to provide a restrained ceiling; nevertheless, they do not require bracing assemblies unless they are larger than 1000 sq. ft.
- For Seismic Design Category D, E & F, these details typically include requirements for perimeter closure that provides fixity along two adjacent sides and allows ¾" of slip on the opposite sides as well as periodic bracing assemblies in ceilings larger than 1000 sq. ft. ASTM E580 includes requirements for the strength of connections between grid elements, minimum size (2") for the closure angle, requirements for seismic separation joints for ceilings larger than 2500 sq. ft., requirements for the support of lighting and mechanical services, etc. Check with ASTM E580 for applicable spacing, exemptions, and other requirements.
- Where lights and diffusers and supported by the ceiling grid, either an intermediate duty or heavy duty grid must be used and supplementary framing and hanger wires may be required to provide direct support for such items. For instance, ASTM E580 requires heavy duty main runners with a load carrying capacity of 16 lb/ft for Seismic Design Category D, E and F. If cross runners with a load carrying capacity less than 16 lbs/ft are specified, and the corner of any light fixture is supported on two adjacent sides by these intermediate duty cross runners, then a supplementary hanger wire must be attached to

the grid within 3" of each such corner. ASTM E580 includes several figures showing examples where these supplementary wires are required. These supplementary hanger wires are not required where heavy duty cross runners are specified; for instance, DSA IR 25-5 *Metal Suspension Systems for Lay-in Panel Ceilings* (California Department of General Services, 2009c), requires all lights to be supported by heavy duty runners. In order to minimize their potential falling hazard, lights, diffusers and similar items are required to have independent safety wires attached directly to the structure. The number and configuration of these safety wires varies depending on the size and weight of the items. See Examples 6.4.6.2 and 6.4.9 for additional requirements for ail diffusers and lights, respectively.

- Seismic bracing assemblies for suspended ceilings typically include a vertical compression strut and diagonally splayed wire braces as shown in Figure 6.3.4.1-8. Rigid bracing assemblies, such as those shown to brace overhead piping in Section 6.4.3 may also be used.
- ASTM E580 includes other requirements for clear openings for sprinkler heads, seismic separation joints, ceiling penetrations, and consideration of consequential damage and seismic interaction effects.
- The Division of the State Architect sets forth ceiling standards for California schools in DSA IR 25-5. This reference is a useful tool for designing in areas of potentially severe seismic shaking. In California, schools require ceiling bracing assemblies at a spacing of not more than 12 feet in each direction; essential services buildings require bracing assemblies at a spacing of not more than 8 ft. by 12 ft. on center. DSA requirements differ slightly from those in ASTM E580; check the applicable jurisdiction for specific requirements.
- Ceiling details in Figures 6.3.4.1-6, 7, 8 and 9 are for Seismic Design Category D, E and F where the total ceiling weight does not exceed 4 psf or Seismic Design Category C where the total ceiling weight is between 2.5-4 psf. These are adapted from CA DSA IR 25-5 and ASTM E580. These figures are shown with heavy duty main runners and cross runners as required by DSA IR 25-5; see discussion in text regarding the requirement in ASTM E580 for supplementary hanger wires at light fixtures supported by intermediate duty cross runners. Check the applicable jurisdiction; in some cases, ceilings heavier than 4 psf, or those with a plenum larger than a certain threshold, may require engineering. See sources for additional information, updates, or for connection details and special conditions not shown.

- There are shake table tests of ceilings which show that systems perform better when the tile almost nearly fills the available space and has ample overlap on the runners. These systems also have fewer tiles drop in tests than systems with smaller tiles.
- ASCE 7-10 Section 13.5.6.3 includes a discussion of "integral construction" where the grid, panels, lights, piping, and other overhead services are shop assembled in modules and bracing is provided for the whole assembly. These are included as an alternative to the details shown here. Check the internet for proprietary systems or systems pre-approved for use in your jurisdiction.
- Safety wires are required for lights and mechanical services in suspended acoustic tile ceilings to prevent them from falling. Refer to Sections 6.4.9 and 6.4.6.2 for additional information. As noted above, supplementary hanger wires for the ceiling grid may also be required. The weight of supported items should never exceed the carrying capacity of the ceiling grid. Special details are required for heavy lighting or heavy mechanical items; these should be supported directly from the structure above and not depend on the ceiling grid for vertical or lateral support. For such fixed items, perimeter closure details may be required for the ceiling to prevent impact with the ceiling system.

Mitigation Examples

Figure 6.3.4.1-5 Compression struts and diagonal splayed wires are used to limit the movement of suspended acoustic tile ceilings. Per ASTM E580, this type of bracing assembly is required for ceiling areas larger than 1000 sq. ft. in Seismic Design Category D,E & F. (Photo courtesy of Maryann Phipps, Estructure).

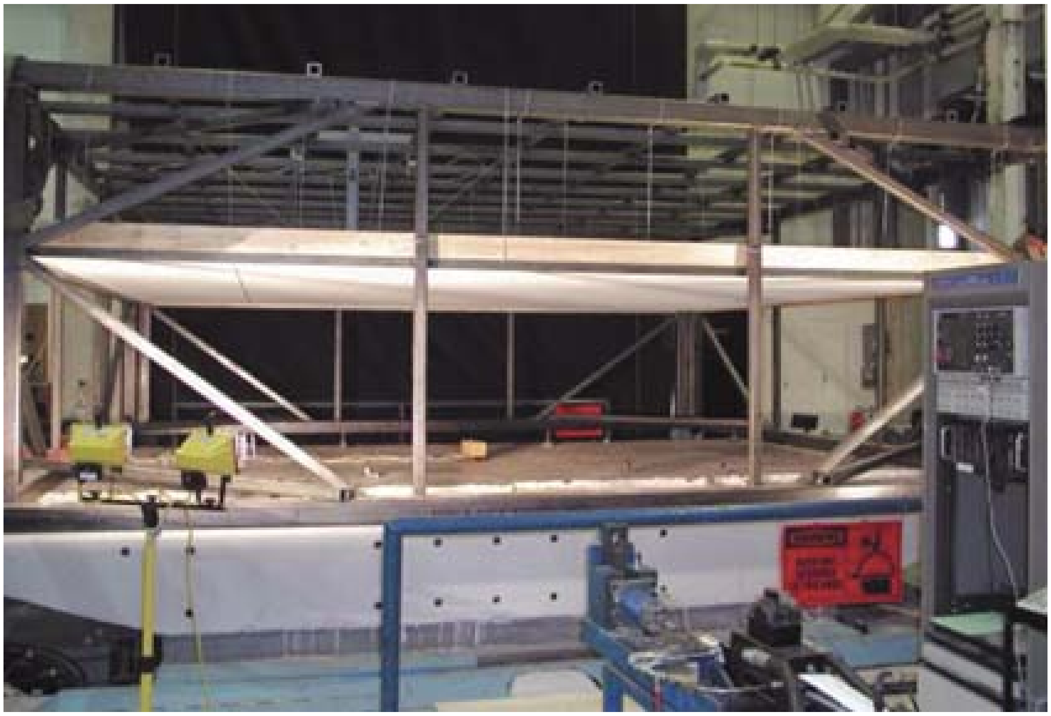


Figure 6.3.4.1-6 Shake table testing of a proprietary suspended acoustic lay-in tile ceiling at MCEER (Photo courtesy of University of Buffalo, SUNY). Additional testing of these systems will help improve our understanding of their failure modes and help inform the design of more resilient systems.

Mitigation Details

Ceiling details in Figures 6.3.4.1-7, 8, 9 and 10 are for Seismic Design Category D, E and F where the total ceiling weight does not exceed 4 psf or Seismic Design Category C where the total ceiling weight is between 2.5-4 psf. These are adapted from DSA IR 25-5 and ASTM E580. These figures are shown with heavy duty main runners and heavy duty cross runners as required by DSA IR 25-5; see discussion in text regarding the requirement in ASTM E580 for supplementary hanger wires at light fixtures supported by intermediate duty cross runners. Check the applicable jurisdiction; in some cases, ceilings heavier than 4psf, or those with a plenum larger than a certain threshold, may require engineering. See sources for additional information, updates, or for connection details and special conditions not shown.

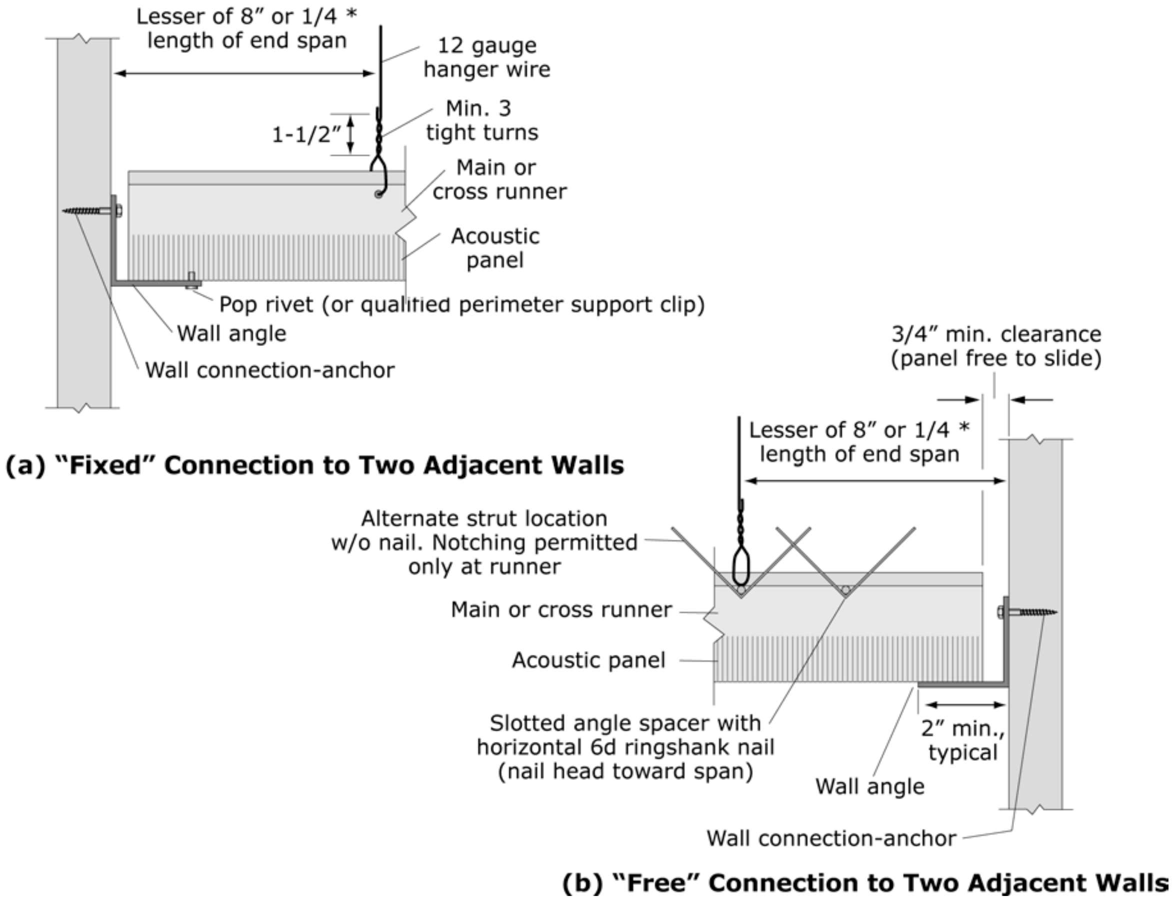
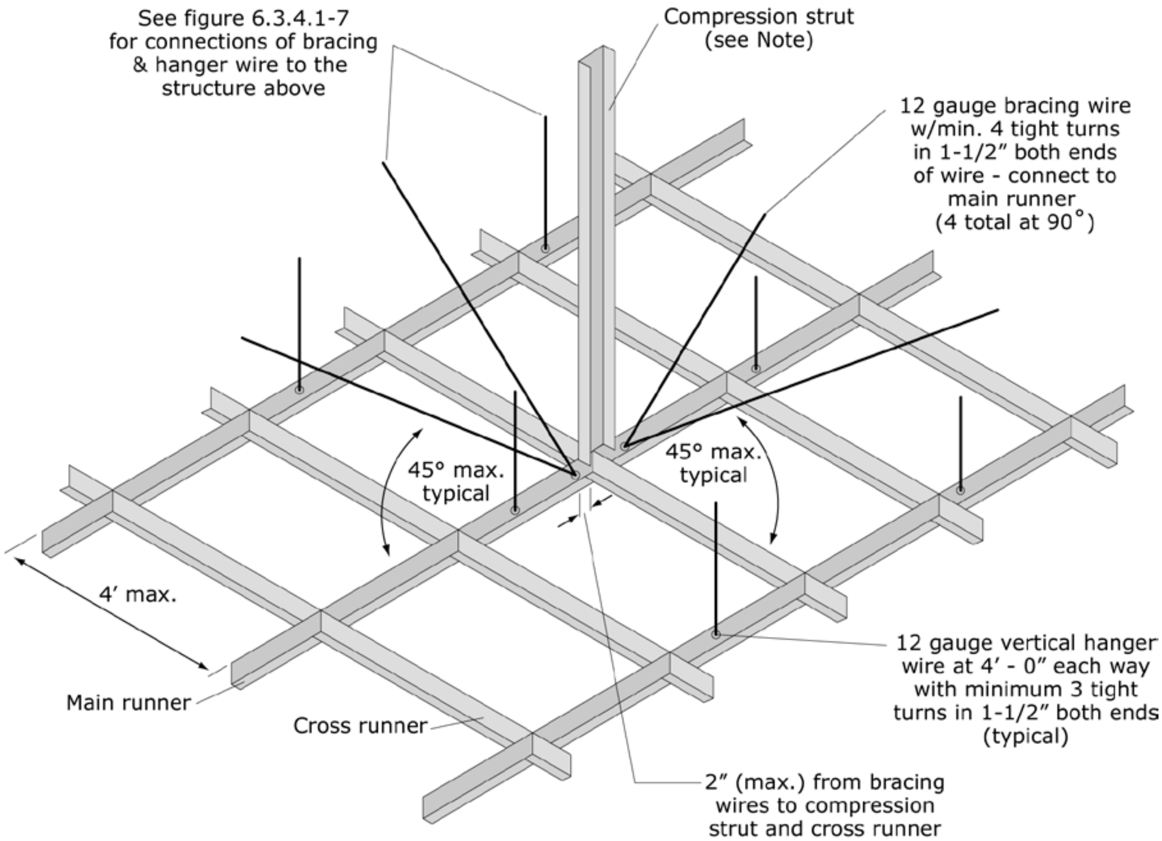


Figure 6.3.4.1-7 Suspension system for acoustic lay-in panel ceilings – edge conditions (PR).



Note: Compression strut shall not replace hanger wire. Compression strut consists of a steel section attached to main runner with 2 - #12 sheet metal screws and to structure with 2 - #12 screws to wood or 1/4" min. expansion anchor to structure. Size of strut is dependent on distance between ceiling and structure ($l/r \leq 200$). A 1" diameter conduit can be used for up to 6', a 1-5/8" X 1-1/4" metal stud can be used for up to 10'

Per DSA IR 25-5, ceiling areas less than 144 sq. ft, or fire rated ceilings less than 96 sq. ft., surrounded by walls braced to the structure above do not require lateral bracing assemblies when they are attached to two adjacent walls. (ASTM E580 does not require lateral bracing assemblies for ceilings less than 1000 sq. ft.; see text.)

Figure 6.3.4.1-8 Suspension system for acoustic lay-in panel ceilings – lateral bracing assembly (PR).

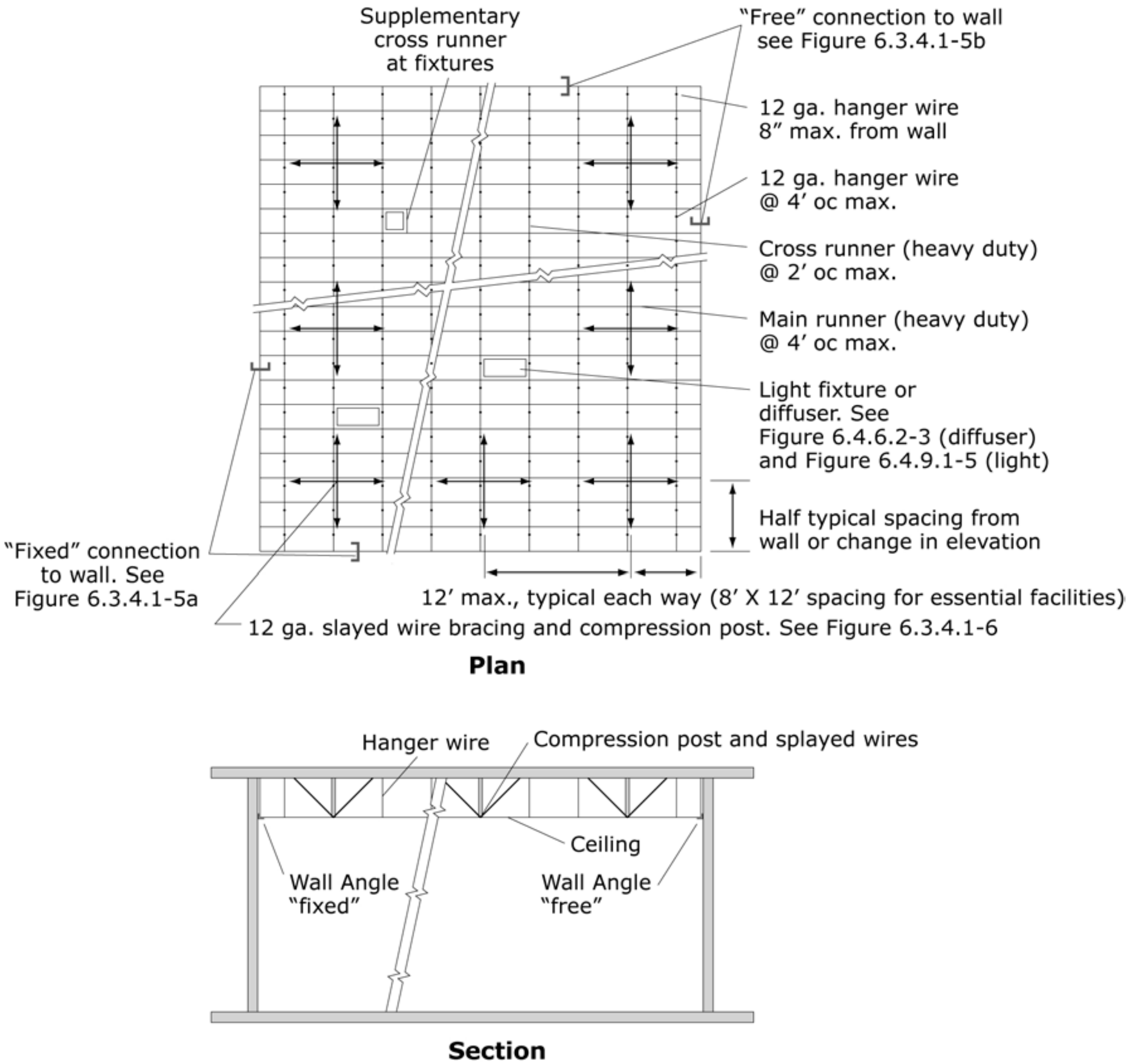


Figure 6.3.4.1-9 Suspension system for acoustic lay-in panel ceiling – general layout (PR).

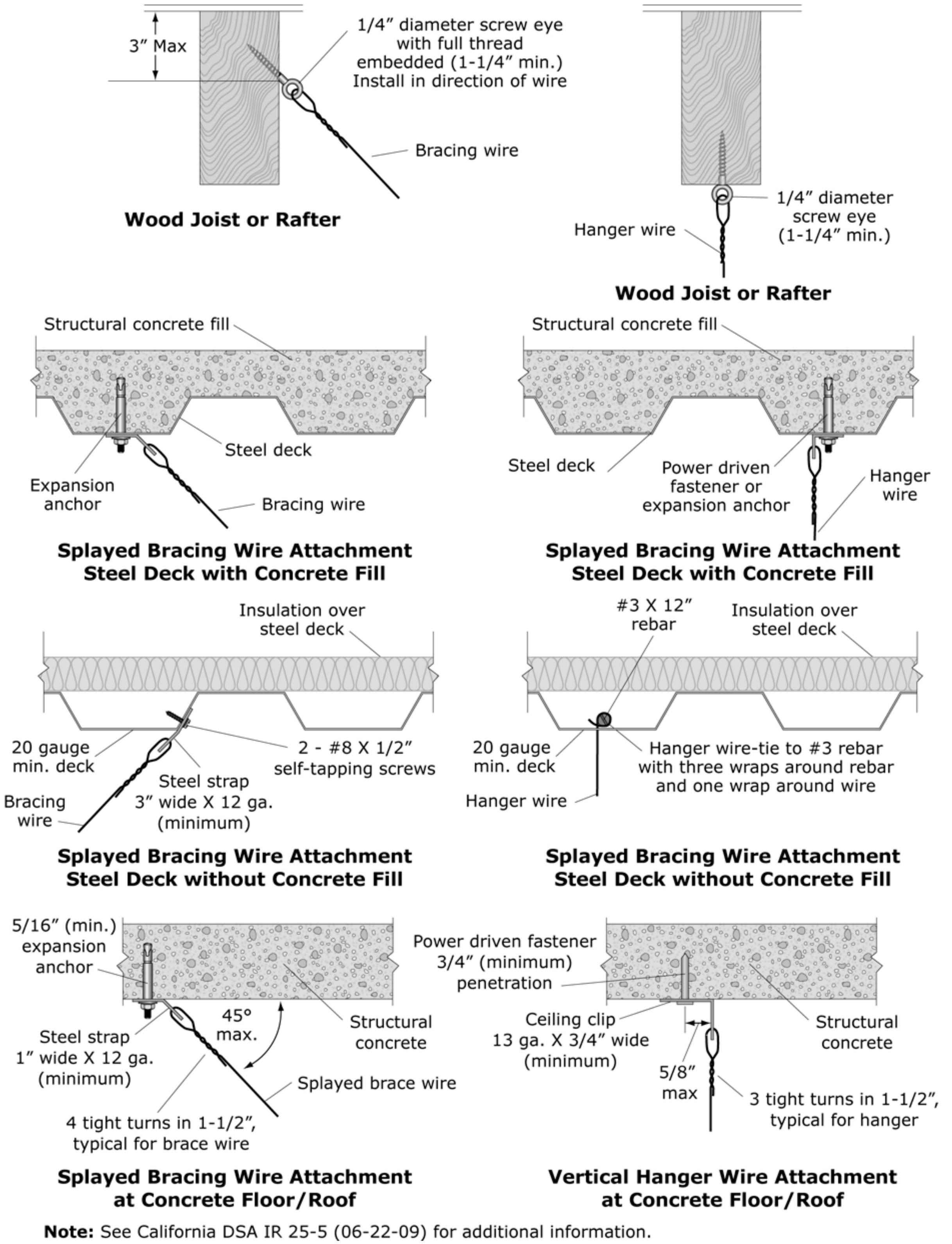


Figure 6.3.4.1-10 Suspension system for lay acoustic lay-in panel ceiling – overhead attachment details (PR).